

## A Comparison of the Nariokotome *Homo erectus* With Juveniles From a Modern Human Population

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**KEY WORDS** *Homo erectus*; human growth and development; skeletal ageing; dental ageing; epiphyseal closure

**ABSTRACT** The Nariokotome *Homo erectus* has an apparent disjunction of inferred age as judged by dental maturity, by epiphyseal closure and by stature, when compared to modern human norms. On this basis, it has been suggested that this fossil hominin differed in its pattern of growth and development from modern humans. In particular, the characteristic human adolescent growth spurt may not yet have been present, and in this sense *H. erectus* growth would be more ape-like than human-like. This study tests this conclusion by examining the variation in age as inferred from the maturity indicators in a modern human skeletal population of known age. The results show that all of the maturity indicators used in this analysis underage the test skeletons. Furthermore, there is also no consistency between the indicators; they do not agree in their inferred chronological ages. The disjunction between the maturity indicators in the test skeletons is similar in pattern to the disjunction observed in the Nariokotome *Homo erectus*. This is particularly true of the relationship between dental age and the other two indicators. These results suggest that the pattern observed in Nariokotome is within the normal range of variation found in modern humans. It does not necessarily indicate a different pattern of growth and development. *Am J Phys Anthropol* 110: 81–93, 1999. © 1999 Wiley-Liss, Inc.

The discovery of the Nariokotome *Homo erectus* (KNM WT 15000) gives us a rare opportunity to examine hominin<sup>1</sup> growth and development. This specimen, dating to 1.6 million years, is the most complete early hominin yet found (Brown and McDougall, 1993). The skeleton has been sexed as male on the basis of assessment of the sciatic notch, the robusticity of the skull, and the general size (Ruff and Walker, 1993). The epiphyses of the long bones and pelvis have yet to close and the jaws retain the upper deciduous canines. This stage of development indicates a subadult (Walker and Leakey, 1993).

The physiological age of the Nariokotome *H. erectus* was estimated by Smith (1993) using three maturity indicators, dental maturity, epiphyseal closure, and the stature of the specimen. Smith found that the age estimates from each of these indicators did not agree. The methods used to estimate dental age gave a range from 10.5 to 11.3 years. Smith concluded that a dental age of about 11 years old was most consistent with the data. The Nariokotome youth's skeletal age is estimated at between 13 and 13.5 years old. This is based on the fact that the epiphyses of the distal humerus had begun

<sup>1</sup>According to recent taxonomic practice, "hominin" is used here in preference to "hominid" to refer to all members of the human line since its separation from that leading to the African apes.

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to unite but the triradiate cartilage of the pelvis is still open (Smith, 1993). In human males, the distal humerus begins to fuse between 11 and 15 years of age, with full closure of the epiphyses between 14 and 16 years of age. The triradiate cartilage of the male pelvis unites between 13 and 15 years old.

The stature of the Nariokotome youth has been estimated at 160 cm (Ruff and Walker, 1993). This estimate is based on femur and tibia lengths and assumes normal human growth and normal human body proportions. In most populations, a mean stature of 152 cm is reached between 12 and 15 years old (Smith, 1993). At 160 cm, the Nariokotome boy is, therefore, tall for early adolescence. His stature would indicate an individual well into the adolescent growth spurt; therefore, his age for stature is estimated as 15 years old.

Although the Nariokotome youth's stature and skeletal age indicate that by modern standards he would be well into his adolescent growth spurt, his dental age would indicate a stage prior to this spurt in growth. He would undoubtedly fit human development at some percentile, but would neither fit into the average position nor would he look ordinary (Smith, 1993). Smith, therefore, proposes that *H. erectus* growth and development was different from modern humans. In particular, she proposes that *H. erectus* was yet to develop the adolescent growth spurt. This inference is based on the assumption that in a modern adolescent all maturity indicators would be in agreement with each other and give age estimates close to actual chronological age.

The present study explores the relationship between these maturity indicators in a modern human skeletal population of known age. It also examines the predictive value of these indicators in estimating chronological age. The results are then used to test the conclusion that the Nariokotome *H. erectus* differed from modern humans in its pattern of growth and development.

## MATERIALS AND METHODS

The sample population was drawn from the Spitalfields collection of 18<sup>th</sup> and 19<sup>th</sup> century Londoners of Huguenot ancestry. The collection is currently housed at the Natural History Museum in London. There

are only ten juveniles of known age (5.4–18.5 years) in the Spitalfields collection with enough evidence of all three maturity indicators to be included in the sample for the study. The ages were derived directly from coffin plates, and ages were confirmed where possible by cross-checking dates in baptismal and burial registers (Molleson and Cox, 1993). For each skeleton, age was assessed blind on the basis of each of the three maturity indicators used for the Nariokotome *Homo erectus*: dental development, epiphyseal closure, and stature. The stage of dental development was independently confirmed by an impartial assessor to ensure accuracy. The methods used in this study are similar to those used by Smith (1993) in the Nariokotome assessment. Because the Spitalfields sample is of European ancestry, however, European reference populations were used to assess age. The study is limited by the small sample size and the older age of the sample (see Table 1).

Age is inferred from the dentition on the basis of both dental development and stage of dental formation. The principal methods used were originally developed by Moorrees, Fanning, and Hunt (Smith, 1991). The first method is based on the stage of formation of those mandibular teeth that have not yet completed development. One of twelve stages, from formation of the tooth crypt to closure of the root apex, is assigned each tooth. Each stage is then scored. The score for each tooth is the midpoint between the age of appearance of that stage and the next (Smith, 1991). The dental age is the mean of the scores for each of the teeth (Smith, 1991). The second method is based on stage of development of the lower second molar alone and is assessed on the basis of formation stages. The second molar is assigned a score for its stage of development. This score is the chronological age at which 50% of the reference population had attained this stage of development (Smith, 1991). The dental age used in this analysis is the mean age based on these two techniques. Table 2 provides the dental scores and inferred ages for each tooth for the Spitalfields individuals and for the Nariokotome youth. Two other methods, Schour and Masslers' dental atlas (Hillson, 1986) and the scoring system for four teeth developed by Demirjian and Gold-

TABLE 1. The chronological, dental, skeletal and stature ages of the Spitalfields sample

Specimen no.	Chronological age	Sex	Skeletal age (years)	Dental age (years)	Stature (cm)	Age for stature (years)
2730	5.4	Male	4.0	4.7	107.7	4.6
2266	7.9	Male	8.0	6.9	118.9	6.7
2139	10.4	Male	6.0	9.3	144.9	11.4
2677	12.0	Female	10.4	9.4	133.7	9.5
2721	14.0	Female	14.25	12.8	155	13.0
2175	15.1	Female	16.6	15.4	155.7	13.0
2755	16.5	Female	15.0	11.5	154.9	12.7
2104	16.6	Male	14.9	12.5	171.7	15.8
2752	17.5	Female	15.8	13.7	153.5	12.5
2308	18.5	Female	15.5	13.9	161.0	15.0

The assessment of age of the Spitalfields test skeletons used similar methods to those employed by Smith (1993) when determining the physiological age of the Nariokotome *H. erectus*. As the Spitalfields skeletons are European in origin, their stature was determined using the Trotter and Glesser equations for European population (Brothwell, 1972). Boys: height = 1.31 (femur length + fibula length) + 63.03. Girls: height = 0.68 humerus length + 1.31 femur length + 1.15 tibia length + 50.12. See Tables 2 and 3 for determination of dental and skeletal ages.

TABLE 2. Predicted age from stage of tooth formation\*

	I <sub>1</sub>	I <sub>2</sub>	C	P <sub>3</sub>	P <sub>4</sub>	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	Mean <sup>1</sup>	M <sub>2</sub> <sup>2</sup>	Dental
2730	Ri	Ri	Cr3q	Crh	Crh	Rq	Coc	—			
	—	—	3.4	4.1	5.0	4.9	4.9	—	4.7	4.7	
2266	Rc	Rc	Rq	Ri	Crc	Ah	Crc	—			
	7.3	8.3	6.9	6.4	6.6	8.5	6.8	—	7.3	6.5	6.9
2139	Ac	Ah	Rh	R3q	Rh	Ac	Rh	Coc			
	(>8.1)	8.9	8.8	10.2	10.1	(>9.4)	10.6	10.6	8.4	10.1	9.3
2677	Ac	Ac	Rc	R3q	Rh	—	Rq	—			
	(>7.7)	(>8.5)	9.4	9.6	9.4	—	9.5	—	9.5	9.2	9.4
2721	—	Ac	Ac	Ac	Ah	Ac	Ah	Crc			
	—	(>8.5)	(>11.3)	(>12.2)	12.8	(>8.7)	13.5	12.6	13.0	12.5	12.8
2175	—	—	Ac	Ac	Ac	Ac	Ac	Rh			
	—	—	(>11.3)	(>12.2)	(>13.7)	(>8.7)	(>14.6)	16.2	16.2	14.6	15.4
2755	Ac	Ac	Ac	Ac	Ah	Ac	R3q	Ri			
	(>7.7)	(>8.5)	(>11.3)	(>12.2)	12.8	(>8.7)	11.0	13.2	12.3	10.7	11.5
2104	Ac	Ac	Ac	Ah	Ah	Ac	Rc	Rq			
	(>8.1)	(>9.3)	(>13.0)	12.7	13.5	(>9.4)	12.3	14.8	13.3	11.7	12.5
2752	—	—	Ac	—	Ah	—	Ac	—			
	—	—	(>11.3)	—	12.8	—	(>14.6)	—	12.8	14.6	13.7
2308	Ac	Ac	Ac	—	—	Ac	Ac	Ri			
	(>7.7)	(>8.5)	(>11.3)	—	—	(>8.7)	(>14.6)	13.2	13.2	14.6	13.9
WT	Ac	Ac	R3q	R <sub>2/3</sub>	R <sub>2/3</sub>	Ac	Rh	Cr <sub>2/3</sub>		11.3–11.7	
	(>8.1)	(>9.3)	9.9	9.7	10.3	(>9.4)	10.6	11.5	10.4	11.7	11.0
15000	(>8.1)	(>9.3)	9.9	9.7	10.3	(>9.4)	10.6	11.5	10.4		

\*The dental age predictions for Spitalfields are based on the Moorees, Fanning, and Hunt's table of tooth formation in Smith (1991). Stages for KNM-WT 15000 are taken from Smith (1993). For each individual the upper row represents stage of crown or root formation and the lower row the inferred age in decimal years. The stages of tooth formation are: Cco = coalescence of cusps; Crc = crown complete; Ri = initial root formation; Rq = root length 1/4; Rh = root length 1/2; R2/3 = root length 2/3; R3q = root length 3/4; Rc = root length complete; Ah = apex half closed; Ac = apex closed. Ages indicated as "less than" or "greater than" not included in mean age calculations.

<sup>1</sup> Midpoint between age of appearance of that stage and the next (Smith, 1991).

<sup>2</sup> The score for stage is the chronological age at which 50% of the reference population attain this stage of development (Smith, 1991).

stein (1976) were also used. They gave ages broadly similar to those obtained from the method of Moorrees et al. These results are not included in the analysis, as they are not

directly comparable to Smith's methods. All methods used were developed on the basis of North American populations of European ancestry.

TABLE 3. Age predicted from stage of epiphyseal closure\*

Epiphysis	2730	2266	2139	2677	2721	2175	2755	2104	2752	2308	15000
Humerus gt tubercle	—	3 8.0	—	3 8.0	3 8.0	4 >8.0	4 >8.0	4 >8.0	—	—	—
Humerus distal	—	—	—	1 12.75	3 14.5	3 14.5	3 14.5	2 13.6	3 14.5	—	3 11.0–15 <sup>3</sup>
Pelvis primary parts	—	—	—	—	3 14.0	3 14.0	3 14.0	3 14.0	3 14.0	—	0
Radius proximal	—	—	—	—	—	3 15.0	3 15.0	3 15.0	3 15.0	—	—
Ulna proximal	—	—	—	—	—	3 15.0	2 13.9	3 15.0	3 15.0	2 13.9	—
Humerus med. condyle	—	—	—	—	—	2 14.75	2 14.75	3 15.5	—	—	—
Tibia distal	—	—	—	—	—	3 15.75	3 15.75	—	3 15.75	2 14.9	—
Femur head	—	—	—	—	—	3 17.5	—	1 15.75	1 15.75	1 15.75	—
Femur gt. trochanter	—	—	—	—	—	3 17.5	—	1 15.25	1 15.25	—	—
Femur less trochanter	—	—	—	—	—	3 17.5	—	—	1 14.25	—	—
Femur distal	0 <sup>1</sup> 4	—	—	—	—	2 17.4	—	—	1 16.75	—	—
Tibia proximal	—	—	—	—	—	2 17.4	—	—	1 16.75	2 17.4	—
Radius distal	—	—	—	—	—	2 17.75	—	—	2 17.75	—	—
Ulna distal	—	—	—	—	—	1 17.5	—	—	—	—	—
Scapula acromion	—	—	—	—	—	2 17.9	1 17.25	—	—	—	—
Pelvis crest	—	—	—	—	—	1 17	—	—	1 17	—	—
Pelvis tubercle	—	—	—	—	—	1 17.25	—	—	1 17.25	—	—
Humerus proximal	—	—	0 <sup>2</sup> 6.0	—	—	2 18.9	—	—	—	—	—
Scapula vert. margin	—	—	—	—	—	1 17.0	—	—	—	—	—
Scapula inferior angle	—	—	—	—	—	1 17.0	—	—	—	—	—
Skeletal age	4.0	8.0	6.0	10.4	14.25	16.6	15.0	14.9	15.8	15.5	13.0

\* Skeletal age for stage for the Spitalfields sample from Krogman and Iscan (1986). Upper row is the stage of epiphyseal closure, the lower row is the average age this stage attained. 0 = not closed; 1 = closure just begun; 2 = almost complete; 3 = newly closed; 4 = complete closure. Ages for stage 1 are the mean of the age range for beginning closure. Ages for stage 2 are the mean of stages 1 and 3. Ages for stage 3 are the mean of the age range for completion of closure. Ages for stage 4 are the oldest ages for complete closure. All ages are in decimal years.

<sup>1</sup> Patella present, distinguishable at 4 years old.

<sup>2</sup> Epiphysis present, but not fused distinguishable at 6 years old.

<sup>3</sup> Taken from Modi and Flecker cited in Krogman (1962).

Skeletal age is inferred on the basis of epiphyseal closure using the five-point scale developed by McKern and Stewart on the basis of North American populations of European descent (in Krogman and Iscan, 1986). All long bones, the pelvis, and scapula are used in the maturity assessment. Table 3 provides the inferred ages based on each epiphysis for each individual in the sample and the mean skeletal age derived for each individual and the ages predicted for the Nariokotome youth.

Stature is estimated on the basis of the length of the long bones using the Trotter and Gleser equations for European populations (Brothwell, 1972, see Table 1 for equations). The Trotter and Gleser equations are for adult individuals. Equations for juveniles may produce different results. However, because statures for both Spitalfields and Nariokotome are based on adult equations, the results are internally consistent. Age was then determined for stature on the basis of reference London samples in Eveleth and

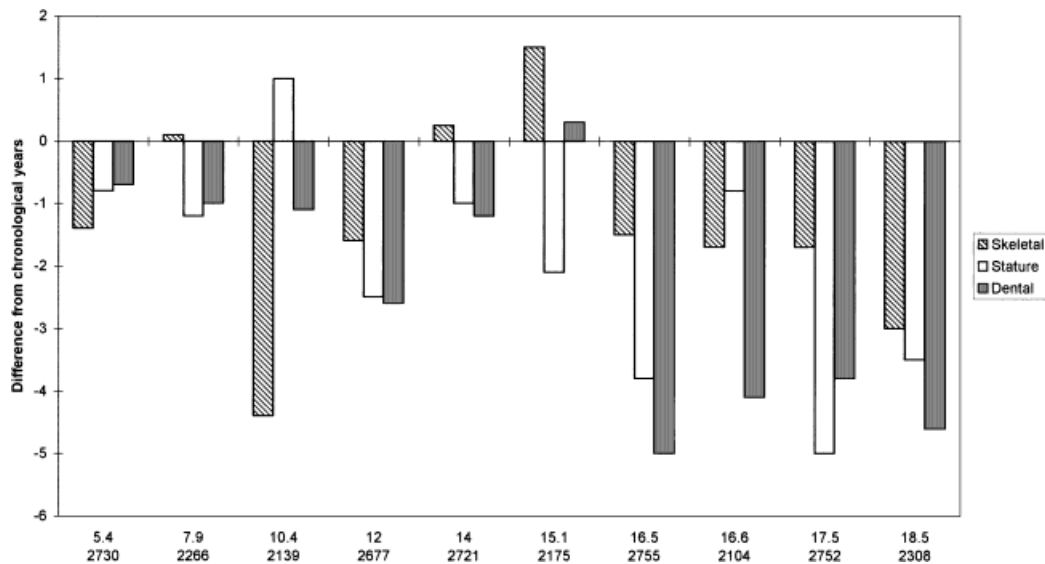


Fig. 1. The variability in inferring age from maturity indicators in the Spitalfields test skeletons. Three measures of maturity are used, skeletal (epiphyseal closure), dental, and stature. (See Table 1 for the equations for stature estimates.) The figures immediately below the line are chronological (known) age in decimal years. The four digit numbers on the lower border are the specimen numbers of the Spitalfields skeletons.

Tanner (1976). The estimated dental, skeletal and height ages for the Nariokotome *H. erectus* are taken from Smith (1993). His estimated height is taken from Ruff and Walker (1993).

## RESULTS

In all but one case (specimen no. 2175, Table 1), age based on dental maturity (dental age) underestimates age in all the Spitalfields juveniles. In some cases, this underestimation is small. Most of the over 15-year-olds in the sample, however, have an inferred dental age that is much younger than their chronological age. The age estimates from epiphyseal closure (skeletal age) are closer to chronological age (Table 1). This is particularly true for the older individuals (specimen nos. 2755, 2104, 2721, 2752, 2308). Age prediction from stature (stature age) underestimates age in all but one specimen (specimen no. 2139). The youngest individuals are underaged by 10 months, while the older individuals are up to 5 years older than their stature would suggest. By modern standards, the Spitalfields juveniles are short for their ages. No single maturity indicator

accurately predicts the chronological age of any individual in the sample, if accuracy is defined as within 6 months of chronological age. There is also a mismatch between the maturity indicators. They do not agree in their prediction of chronological age (Fig. 1).

For most of the Spitalfields sample and for the Nariokotome youth, skeletal age based on epiphyseal closure is greater than dental age (Fig. 2). The difference between these two age estimates ranged from 1 to 3.5 years. Age based on stature is also greater than dental age, although in some cases this difference is less marked than for the skeletal age (Fig. 3). The difference between inferred ages ranges from 1 month to 4 years. Based on stature, the Spitalfields sample has a younger inferred age than it does when age is based on epiphyseal closure. In other words, the Spitalfields juveniles are short for their stage of skeletal development in relation to modern comparative samples. This is the opposite pattern to that observed in the Nariokotome data (Fig. 4).

Not only is Nariokotome tall in relation to his stage of skeletal development, he is also

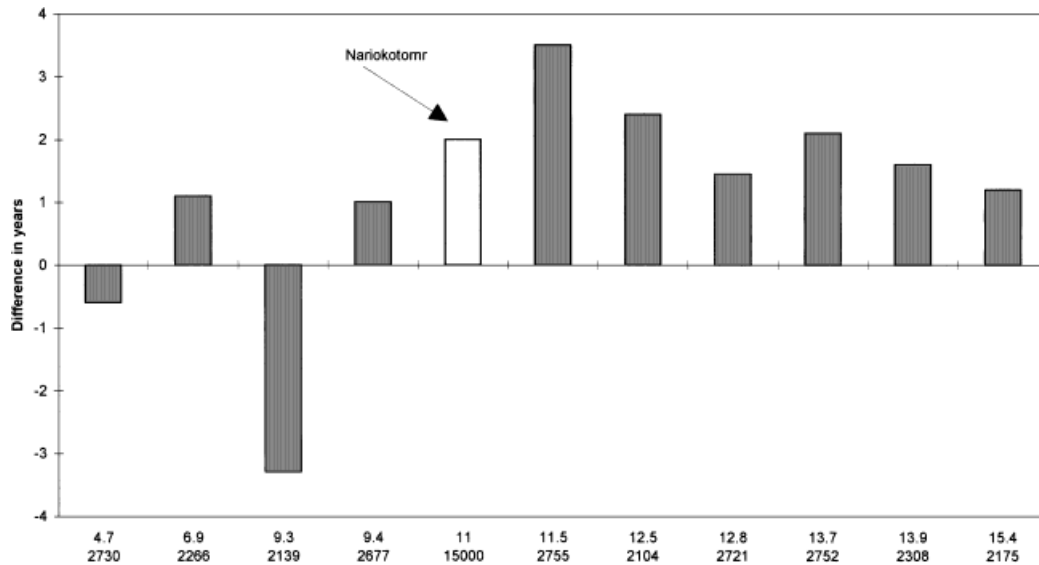


Fig. 2. The difference between dental age and skeletal age in the Spitalfields test skeletons and the Nariokotome *H. erectus*. There is a mismatch between dental and skeletal ages in all individuals. In most cases, skeletal age is in advance of dental age by between 1 and 3.5 years. Dental age (years) is shown below the specimen number below the x-axis. Difference in years is the difference between skeletal age and dental age, which is represented by the horizontal reference line.

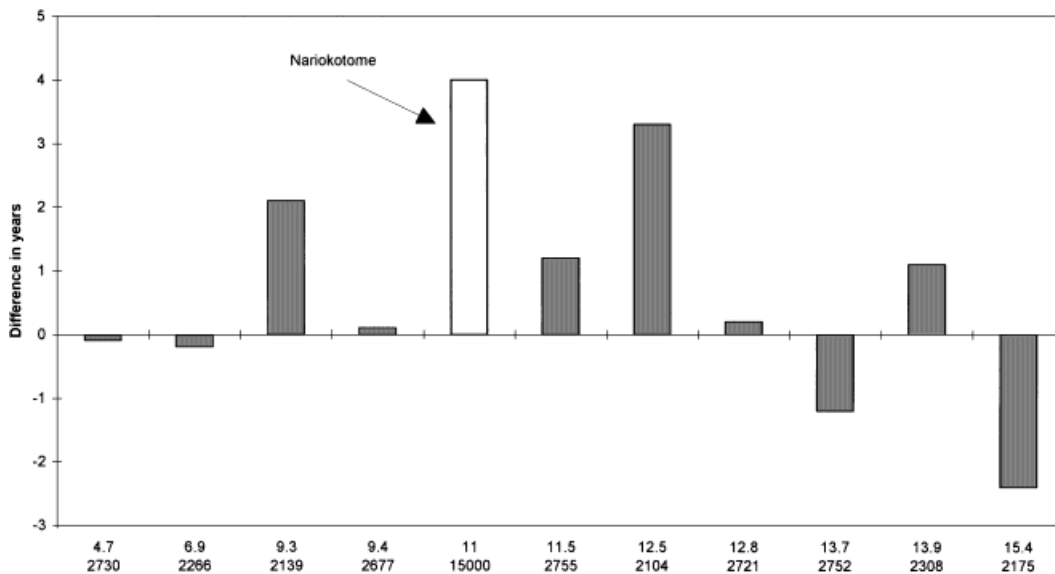


Fig. 3. The difference between dental age and stature age in the Spitalfields test skeletons and the Nariokotome *H. erectus* shows that in most cases stature age is greater than dental age. Dental age (years) is shown below the specimen number on the lower border. Difference in years is the difference between stature age and dental age, which is represented by the horizontal reference line.

tall in relation to absolute age based on modern European populations. For example, if the Nariokotome youth was 11 years of age as indicated by his stage of dental develop-

ment, he would be on the 97<sup>th</sup> percentile based on a large reference population of school children from New South Wales (Jones et al., 1973; Fig. 5). In relation to stature,

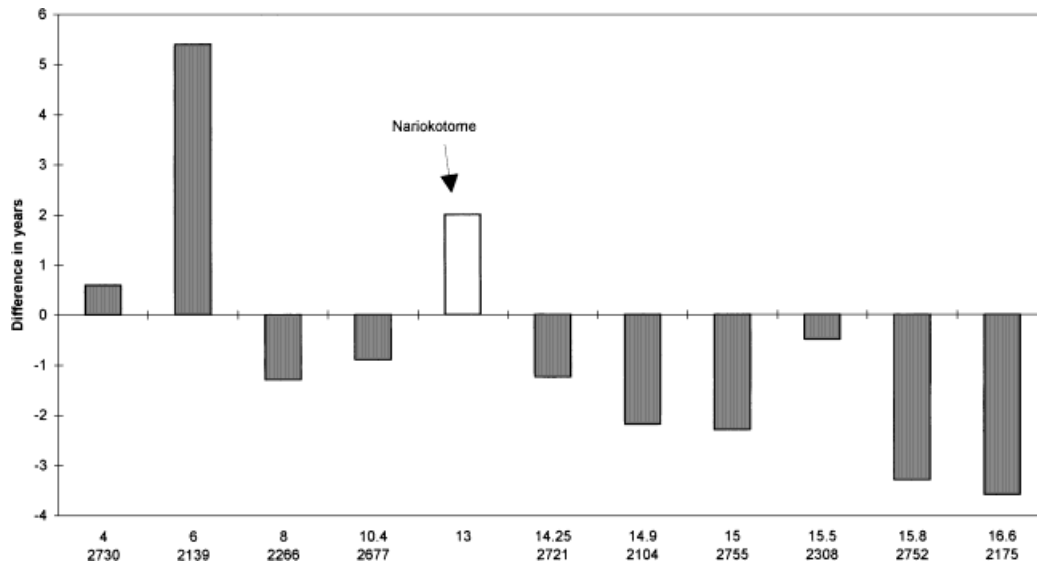


Fig. 4. The difference between skeletal age and stature age in the Spitalfields test skeletons and the Nariokotome *H. erectus* shows a consistently younger stature age than skeletal maturity would indicate in nine of the Spitalfields skeletons. This is the opposite pattern to the Nariokotome *H. erectus*. One specimen

(2139) shows a similar, but more extreme pattern than the Nariokotome youth. Skeletal age (years) is shown below the specimen number on the lower border, and the difference in years is the difference between skeletal age and stature age, which is represented by the horizontal reference line.

the Spitalfields test skeletons, with one exception, fit within the range of modern variation of this sample. None are above the 50<sup>th</sup> percentile for their chronological age, while one is below the 3<sup>rd</sup> percentile. They are therefore, almost all short for their chronological age. In relation to dental development, some of the Spitalfields skeletons are just outside the range of the percentiles based on modern humans (Figs. 6 and 7). The stage of dental development was independently confirmed by an impartial experienced assessor. The overall pattern of dental formation in relation to age in the Spitalfields juveniles is consistent with the pattern and range of variation found by Moorrees et al. (1963) (Fig. 8). As a result, we are confident that the dental ages for the Spitalfields juveniles accurately reflect the stage of dental development and not any fundamental errors in determining the dental ages of the individuals.

## DISCUSSION

The Nariokotome youth shows a disjunction between maturity indicators. On this basis, he is regarded as having a pattern of growth and development that is not like that

of modern humans (Smith, 1993). The Spitalfields sample also shows a disjunction between maturity indicators, as well as a disjunction between age inferred on the basis of maturity and known chronological age. When the Nariokotome youth is compared to the Spitalfields juveniles, a similar pattern of disjunction is evident between dental age and both skeletal and stature age. However, when skeletal age is compared to stature age, a different pattern emerges. Based on stature, the Nariokotome youth is older than he would be based on the degree of skeletal maturity (epiphyseal closure). In contrast, the Spitalfields juveniles consistently have a younger stature-based age than their degree of skeletal maturity suggests. If the stature prediction for the Nariokotome youth is correct, he was, by modern standards, tall for his stage of development, while the Spitalfields children are small for their stage of development.

The Spitalfields sample and the Nariokotome *H. erectus* were assessed for age on the basis of modern European standards. The use of European standards presents problems when interpreting data from both non-European and historic populations. The last



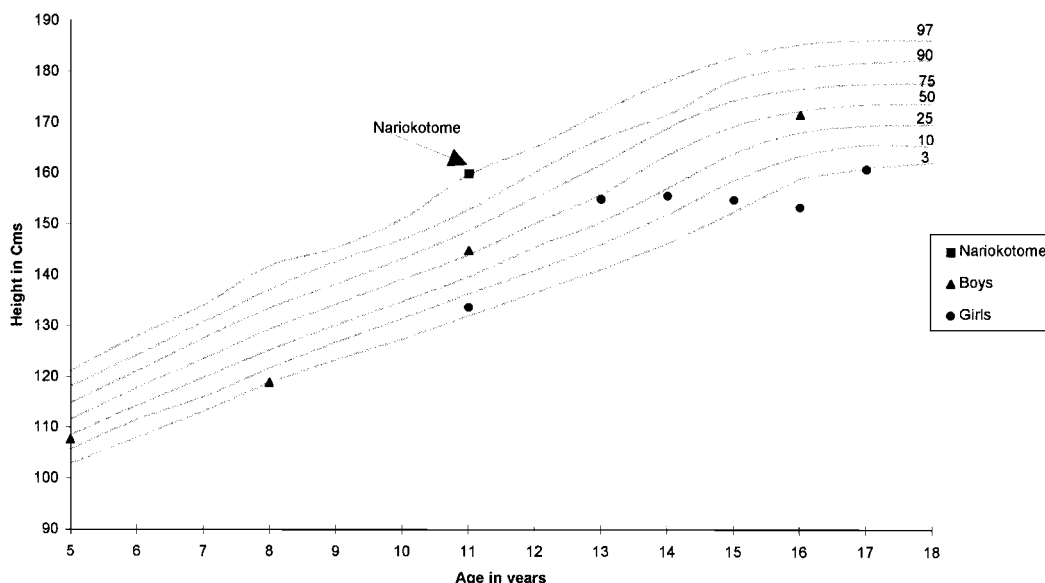


Fig. 5. A comparison of the height of the Nariokotome *H. erectus* and the Spitalfields test skeletons with height percentiles taken from a study of New South Wales schoolchildren (Jones et al., 1973). The height percentiles are those for New South Wales boys. In the study, Jones et al. (1973) found that older girls (over 10 years) reach a given height 6–10 months earlier than

the boys in the study. As the Spitalfields girls are over 10 years old, their ages were rounded down to the nearest year to accommodate both sexes on the same graph. The Nariokotome *H. erectus* has an estimated height of 160 cm. This estimate is based on femur and tibia lengths and uses East African males as a reference population (Ruff and Walker, 1993).

100 years has seen a secular trend in western industrial societies for larger size and earlier maturation (Eveleth and Tanner, 1976). This trend is related to better sanitation, improved medical care, and access to regular supplies of food. Eveleth and Tanner (1990) propose, however, that these factors may not be sufficient by themselves to explain the increase in size and acceleration of the rate of maturation seen, in particular, in European populations. The loss of weaning stress (Eveleth and Tanner, 1990), through the introduction of protein-rich foods, in western societies may be important in reducing the slow down in growth and maturation normally associated with weaning stress (Eveleth and Tanner, 1990).

When modern growth standards are applied to non-European populations, who can be used as a model for archaeological populations (Lampl and Johnston, 1996), there is a lack of agreement between skeletally or dentally inferred age and chronological age. Brown and Graves (1976) found Australian Aborigines less mature dentally and skel-

etally for their chronological ages when compared to Europeans. Likewise, Lampl and Johnston (1996) in a recent study of Mexican children showed consistent underaging. This evidence suggests that the maturation rate of earlier populations may also have been slow when compared to modern Europeans. The Spitalfields sample is in almost all cases older than age estimates based on modern standards would indicate. Their maturation rate would indeed appear to be slower.

Studies of different populations have shown a stature difference between affluent and non-affluent populations (Schmitt and Harrison, 1988). The difference in mean adult stature may be as large as 10 cm. This is a consequence of the trend to larger size in more westernised populations. When assessing stature in historic populations, it should be remembered that a decline in stature occurs with the introduction of agriculture about 9,000 years ago and persisted until recently even in prosperous societies (Walker, 1993). Post-agriculturalists might therefore have more in common with non-affluent



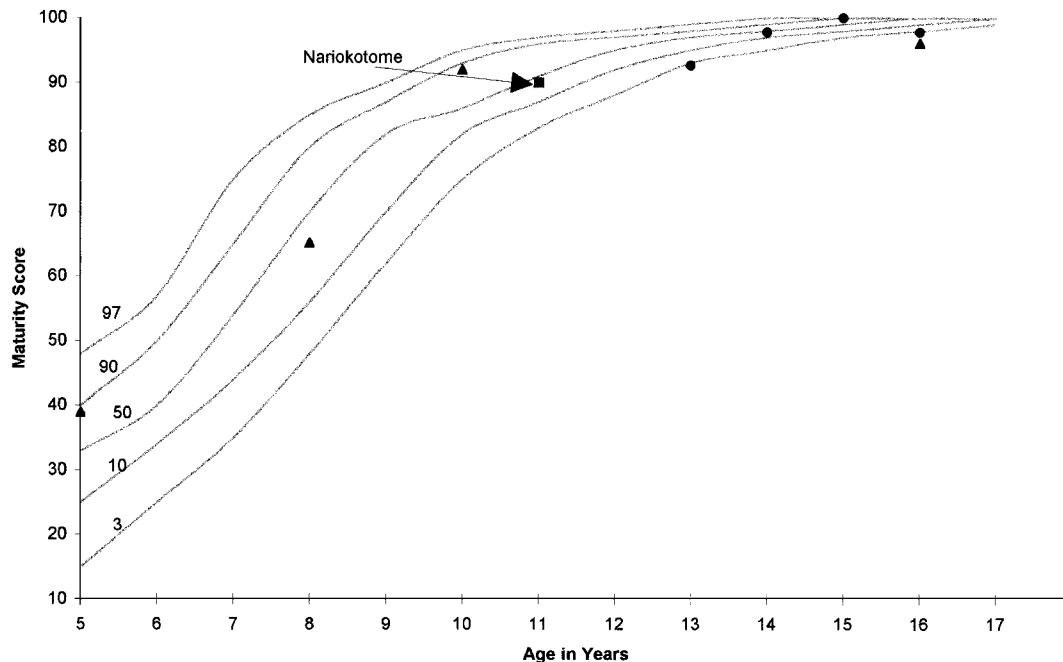


Fig. 6. A comparison of the dental maturity scores of the Nariokotome *H. erectus* and the Spitalfields test skeletons with dental maturity percentiles. The dental maturity percentiles were developed by Demirjian (1976). The percentiles are those for boys. Demirjian's study shows that at a given age girls are dentally more mature

than boys by 6 months to 1 year. The Spitalfields girls' ages were therefore rounded up to the nearest year to accommodate both sexes on a single graph. The Spitalfield juveniles shown on the chart are those for whom x-rays exist. Boys are represented by ▲. Girls are represented by ●.

populations. The greater variety of foods available to the pre-agriculture hunter/gatherers in good environments makes comparisons with affluent populations more plausible. This difference in stature between pre- and post-agricultural populations may explain the Spitalfields sample's consistently short stature compared to the Nariokotome youth.

Ethnic origin has an effect on size and body shape. One factor that illustrates this is the variation in body shape associated with climate. The Nariokotome youth apparently had the long lean body associated with hot climates and seen in present day Turkana pastoralists (Ruff and Walker, 1993). Comparisons with such groups do not explain the Nariokotome youth's unusual stature. Although Turkana adults are tall, their tempo of growth is slower than in westernised populations (Little et al., 1983). In this respect, the Turkana may have more in common with the growth pattern of the Spitalfields children (Fig. 9).

The assessment of age for both the Nariokotome *H. erectus* and the Spitalfields sample is based on mean data. When mean standards are applied to any population, a wide range of variation is found in the rate of maturation. The wide range of variation is also found whenever the target population differs from the reference population. Roche (1986) found a large variation in skeletal maturation at any given age in Melbourne children of European ancestry, while Lampl and Johnson (1996) showed a 4- year range in Mexican children at the same stage of skeletal maturity. Even when the sample is drawn from the reference population, the variation may still be large. Demirjian (1986) found a chronological age range from 15 to 24 months in individuals of the same dental maturity. This individual variation is also important in explaining the differences found in both the Spitalfields sample and the Nariokotome data from modern growth standards.

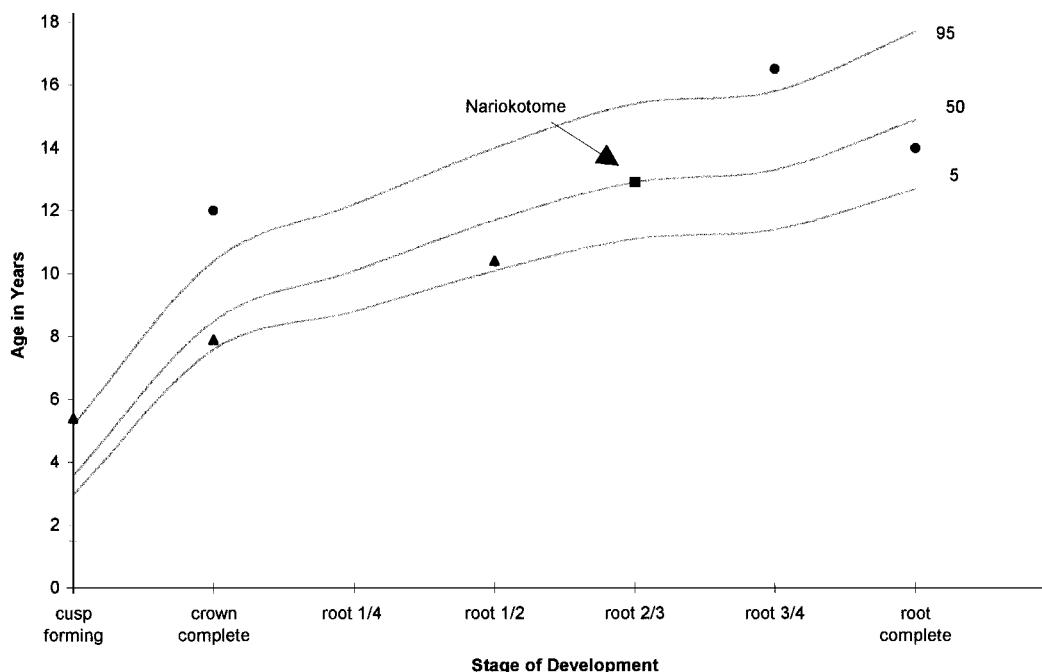


Fig. 7. A comparison of chronological age with the stage of M2 development in the Nariokotome *H. erectus* and the Spitalfields test skeletons. The percentile chart is based on M2 developmental percentiles from Garn et al. (1967). Garn et al. showed that female second molar development was 6 months in advance of male develop-

ment at any given age. The above chart is the boys' percentiles with girls added at known age plus 6 months. The boys are plotted at known chronological age. The Nariokotome *H. erectus* is plotted at his stage of M2 development. Boys are represented by ▲. Girls are represented by ●.

The assumption is often made that maturity indicators should be in agreement in estimating age. However, teeth and bones grow to their own tempo (Tanner, 1986). Furthermore, they are affected differently by environmental stress. Stress slows growth (Tanner, 1986). Repeated or prolonged bouts of environmental stress alter the tempo of growth and affect the final size of the individual (Bielicki, 1986). If the duration of the stress is short, then a period of accelerated growth allows not only the tempo to return to normal but also allows a catch-up period that recovers most or all of the lost growth (Tanner, 1986). Teeth are less affected by environmental stress, but when growth slows there appears to be no catch-up mechanism, and they remain retarded (Guagliardo, 1982).

The growth in any one system varies over time. In any single year, teeth and bones may have more or less growth than might be expected. This will make them look more or

less advanced for a given chronological age. For example, Asian children's bones develop more rapidly than those of Europeans. In 3 chronological years during adolescence, an Asian child is likely to develop skeletally by 4 years, making them seem advanced for their chronological age (Eveleth and Tanner, 1990). This difference between and within systems will affect the accuracy of any age estimates made. Exposure to environmental stress may accentuate the variation between dental and skeletal maturation.

Furthermore, it is generally accepted that dental age will be closer to chronological age than will any other maturity indicator (Smith, 1991). This study has found a closer relationship between skeletal age and chronological age. Other researchers (Green, 1961; Filipsson and Hall, 1976 in Eveleth and Tanner, 1990) have also found skeletal age to have a higher correlation to chronological age than does dental age. It may be that the correspondence between dental age

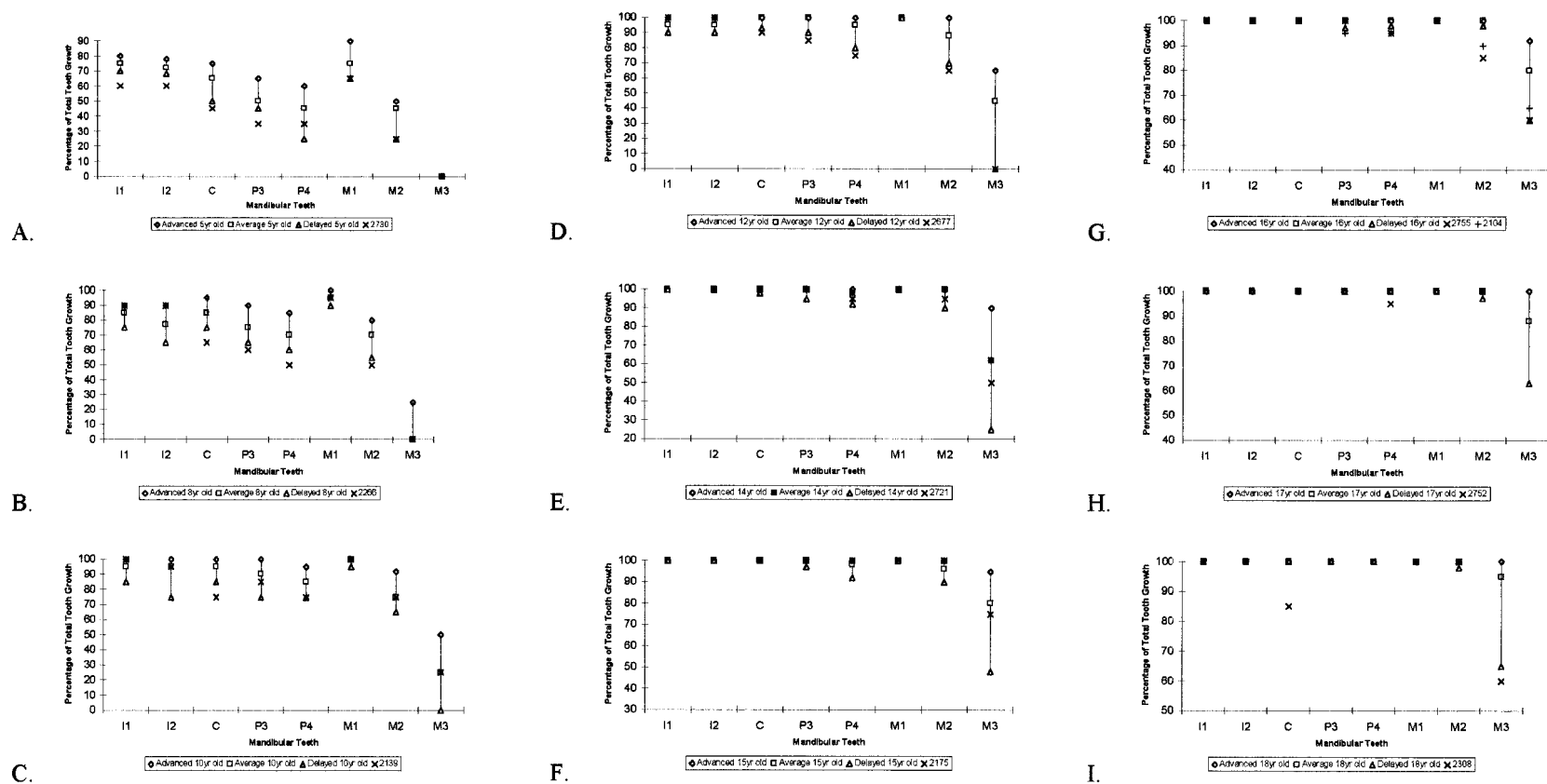


Fig. 8. A comparison of the pattern of dental formation of the permanent dentition of the Spitalfield children with the range of variation in formation stage at a given age. The range of tooth formation stage for each age is based on the range given in Moorrees, Fanning, and Hunt (1963). Dental formation times show less than 6 months difference between boys and girls. Therefore, the dental formation

times for boys are used. Each stage is then converted to an overall percentage of tooth formation (Nolla cited in Lowry, 1986). The formation stages, similar to those used by Moorrees et al. (1963) were: Ci = 10%; Cco = 20%; Cr1/3 = 30%; Cr 2/3 = 40%; Crc = 50%; Ri = 60%; R1/3 = 70%; R2/3 = 80%; Rc = 90%; Ac = 100%.

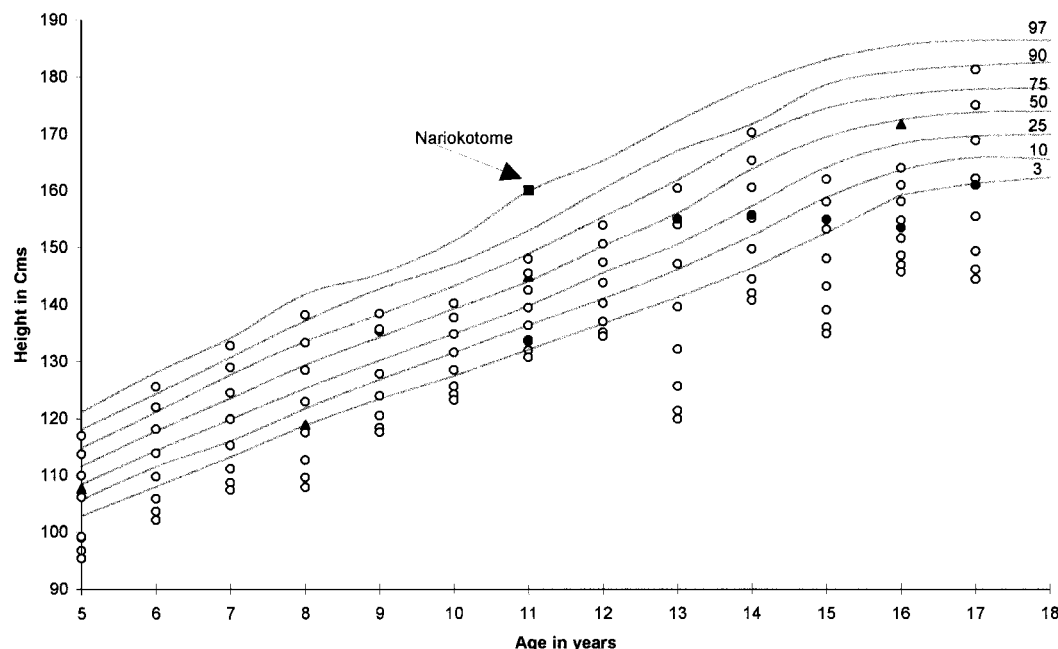


Fig. 9. A comparison of the Nariokotome *H. erectus* with New South Wales height percentiles, the Spitalfields skeletons and the Turkana pastoralists. The Turkana pastoralists' height range is extrapolated from data in the height charts in Eveleth and Tanner (1990) to produce height percentiles. Although the Turkana pastoralists have a tall adult stature, their growth

period extends over a longer time span than is the case most modern Europeans. They only attain their adult stature after the age of 18, when most Europeans have completed their growth (Little et al., 1983). ● represents Spitalfields girls; ▲ represents the Spitalfields boys; and ○ represents the Turkana pastoralists (5<sup>th</sup>–95<sup>th</sup> percentiles)

and chronological age is primarily true for healthy modern westernised populations. It is possible that skeletal age is a better indicator of chronological age in non-western and archaeological populations due to an apparent lack of catch up growth in dental formation after periods of environmental stress. This hypothesis requires further testing.

It should also be remembered that both the Nariokotome youth and the Spitalfields children died young. They may be different in some way from their contemporaries who lived a more normal life span and may therefore not be representative of the populations in which they lived.

### CONCLUSIONS

The results of this study and that of Lampl and Johnston (1996) demonstrate the degree of uncertainty in estimating age from maturity indicators and suggest that the predictive value of mean maturity data is

less than often assumed. Children of the same chronological age have been shown to be at different stages of maturity when compared to these mean data. It is important to exercise caution when ageing past populations (Lampl and Johnston, 1996). The need to use appropriate standards for assessment and to allow for individual variation is essential if a realistic understanding of human growth and development in the past is to be achieved.

If the stature estimate for the Nariokotome youth can be assumed to be correct, he has a greater age for stature than indicated by his stage of skeletal maturity. This is the reverse of the situation found in the Spitalfields children. Environmental factors, particularly the differences between pre- and post-agriculturalists, may have contributed to this distinction. The shared pattern of disjunction between maturity indicators found in the Nariokotome youth and the Spitalfields children is consistent with the

hypothesis that *H. erectus* did have a human-like pattern of growth and development. A similar conclusion has been drawn by Tardieu (1998) on the basis of the femur and by Anton (in press) based on measurements of facial height and vault contours in a number of *H. erectus* sub-adults.

The small size of the Spitalfields sample does not allow any firm conclusions regarding a relationship between maturity indicators or possible patterns of early hominid growth to be drawn. However, this analysis offers no support for the hypothesis that the Nariokotome *H. erectus* lacked the human adolescent growth spurt. This paper represents a starting point for further more detailed study of the relationship between maturity indicators in both modern and ancient populations.

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